

Narcís Monturiol (1819–1885), pioneer of submarine navigation

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Resum. Narcís Monturiol (1819–1885) va tenir un paper destacat en la història de la navegació submarina. Persona de fortes conviccions, va lluitar per la democràcia en una època de canvis i convulsions dins la societat espanyola. Republicà i socialista utòpic va propagar a Catalunya les idees comunistes d'Étienne Cabet. Va organitzar els cabetians entorn del setmanari *La Fraternidad* (1847–1848) i va esdevenir el dirigent del grup icarià de Barcelona. Perseguit i refugiat diverses vegades a Cadaqués, va concebre el seu projecte d'una nau submarina, l'Ictineu o vaixell-peix. Tractat amb recel per les autoritats va poder aconseguir molts suports particulars. Organitzà un equip de tècnics i va dirigir el procés de construcció dels Ictineus. Després d'un primer prototip que va ser avarat a les aigües de Barcelona el 1859, va realitzar millores en un segon Ictineu, avarat el 1864. Monturiol va perfeccionar-lo i, fins i tot, el 1867, va introduir-hi una màquina de vapor. Les dificultats econòmiques van conduir a la fallida del projecte. Autodidacte, Monturiol va rebre, però, el suport de l'elit científica barcelonina. El seu *Ensayo sobre el arte de navegar por debajo del agua* és el primer tractat de síntesi sobre la navegació submarina i una aportació notable a la historiografia de la ciència i de la tècnica.

Paraules clau: Narcís Monturiol · Ictineu · navegació submarina · compromís social dels científics · enginyeria a Catalunya al segle XIX

Summary. Narcís Monturiol (1819–1885) played an essential role in the history of submarine navigation. He was a person of strong convictions and fought for democracy at a time of changes and political convulsions in the Spanish society. Utopian republican and socialist, he spread the Communist ideas of Étienne Cabet in Catalonia, organizing the Cabetians around the weekly, *La Fraternidad* (1847–1848). He also became the leader of the Icarian community in Barcelona. Frequently persecuted because of his political beliefs, he was often forced to seek refuge in Cadaqués, and it was there that he conceived his project of a submarine vessel, the *Ictineu*. Although treated with mistrust by the authorities, he was able to secure sufficient financial and technical support to carry out the project. Together with a team of technicians, he constructed the first *Ictineu*, which was launched in the waters of Barcelona in 1859. Subsequent improvements led to a second *Ictineu*, launched in 1864 and fitted in 1867 with a steam engine. However, economic difficulties led to eventual failure. As an autodidact, Monturiol received the support of Barcelona's scientific elite and continued inventing until his death. His work, *Ensayo sobre el arte de navegar por debajo del agua* (Essay on the Art of Navigating Under Water), was a pioneering, monumental work about submarine navigation and a remarkable contribution to the historiography of science and technology.

Keywords: Narcís Monturiol · Ictineu · submarine navigation · social commitment of scientists · engineering in Catalonia in the 19th century

The engineer, inventor, and political activist Narcís Monturiol Estarriol (Figueres, Spain, 1819–Sant Andreu de Palomar, Barcelona, Spain, 1885) has recently gained well-deserved recognition not only in Catalonia and Spain but also internationally, following publication of the 2003 biography by Matthew Stewart [38]. While Monturiol's work is fixed within Romanticism, his

interpretation of it was not as a historically idealized past; rather, it was based on the belief that these ideals could inspire the future. Monturiol's near-mythic role in the history of science in Catalonia has been discussed elsewhere [30]. This review focuses on Monturiol's many social and technological endeavors and his attempts to realize them. Although during his lifetime he very often met with commercial failure and political disappointment, his achievements in both areas were nonetheless frequently re-examined, elaborated upon, and publicized, both by his devotees and fellow intellectuals and, later, by historians and other academics (Fig. 1).

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The young Monturiol and his fight for democracy

Narcís Monturiol was the son of a cooper, but since he was not the oldest son and thus not the heir to his father's business, he was free to study. He did so in Figueres, at the Vilabertran monastery, which was then a center of teaching. In Figueres, the young Monturiol encountered an atmosphere of intellectual and political motivation in which he was able to develop his interests in technology and science (Fig. 2).

In 1834, he attended the University of Cervera, where he earned a degree in Philosophy, the equivalent of today's high school baccalaureate. He then moved to Barcelona since, at the end of 1836 the university been reinstated. During his law studies, he worked as a printer and journalist, spending the year 1845 in Madrid, where he trained as a typesetter while pursuing his education at the university there. Due to his increasing political activism, however, he did not complete his degree, as, in an act of solidarity, he would inevitably give the money set aside to pay for tuition to his colleagues. As Damas Calvet explains [19]:

"He did not pass the bar because he spent the money on a political cause from that era. His family sent him more and, once again, he used it to help [the activists]."

Even though Monturiol never practiced nor professed to hold a degree in law, his university education was evident in his urbanity and in the refinement and complexity of his writings.

It was during the mid-1840s that Monturiol joined in the fight for democracy in Catalonia. He was associated with a group led by Abdó Terradas, who was also from Figueres and a leading activist in Catalan Republicanism [22]. Monturiol participated as a National Militia officer in the Jamància revolt of 1842–1843, under the orders of Abdó Terradas. From that time on, he was linked to the fight for

emancipation, which he carried on in parallel with his other activities.

As an outgrowth of the events of those years, Monturiol's ideas evolved within the context of socialist thought. In 1844, he published *Un reo de muerte* (Condemned to Death), a text in which he elaborated his opposition to the death penalty and the earliest known writing attributed to him. In 1846, along with the phrenologist Joan Llach i Soliva, he edited *La Madre de Familia* (Mother of the Family), a publication that sought to promote the role of women in the family. It should be noted that some of the texts from this publication are known only because they were reproduced years later by Monturiol himself and by Josep Puig Pujadas, the latter in a biography of Monturiol that is still considered to be the foremost reference on him [33].

In Barcelona, Monturiol's political trajectory led him, in 1847, to found a communist cell loyal to the ideas of the French utopian Étienne Cabet, the only such group in Spain [1]. On 7 November of that year, the Cabetian group published the first issue of its magazine *La Fraternidad* (The Brotherhood), aimed at spreading Cabet's teachings and the European revolutionary movement in general, and to fund Spain's contribution to the founding of the utopian settlement of Icaria. Entreaties for donations and the amounts of the submitted donations were printed in the magazine from the beginning of 1848. In addition, the weekly magazine began publishing the Spanish translation of Cabet's book *Viage por Icaria* (Travels in Icaria). The translation was started by Francisco Orellana and finished some years later by Monturiol.

After the financial support of *La Fraternidad* for Cabet's goal of a preliminary expedition to the United States, one representative from the Iberian Peninsula was aboard the boat that left Le Havre on 3 February 1848: Joan Rovira, a Catalan doctor and a member of Monturiol's Cabetian group. In the following years, at least six other Catalans would join in the adventure. Meanwhile, after 18 issues, *La Fraternidad* came under the suspicion of the authorities, when it published an article in its March 1848 issue on the revolutionary movement taking place in Europe. Monturiol and his colleagues were persecuted. Monturiol exiled himself in France, in the cities of Perpignan and Agen.

In the following years, Monturiol continued his participation in the democratic struggle, heading up the publication *El Padre de Familia* (Father of the Family), a weekly that appeared in 1849 and was suspended by judicial order in 1850, after seven months of publication [2]. In the *Bienio Progresista* (Progressivist biennial), Monturiol was one of the leaders of the Democratic Party. In 1854, for example, he took part in the public action held at Barcelona City Hall's *Consell de Cent* (Council of the One Hundred), in which the protesters demanded freedom of expression, freedom of association, and state secularism [33]. After the 1855 general strike, Monturiol suffered further persecution and fled to Cadaqués, where he had sought refuge on previous occasions and had loyal friends upon whom he could count on [3,36].



Fig. 1. Commemorative logo for the 150th anniversary of the first dive in the *Ictineu I* in the harbor of Barcelona (September 1859), reproduced by permission. For further information: <http://www.ictineu.cat>

The Ictineu

It was during this stay in Cadaqués in 1856 that Monturiol conceived his project for underwater navigation. His source of inspiration was the coral harvesters, whose hardships he witnessed daily. While his invention would be philanthropically motivated, Monturiol also recognized that coral gathering could be a means to profit from underwater navigation. According to Robert Robert, Monturiol had been pondering an attempt at underwater navigation for several years [35]:

“Considering that during the persecution, the events of 1848 attracted men of advanced ideas, Narcís Monturiol was confronted with a pitiful and frequent scene in Cabo de Creus, such that the faculties and feelings that characterize him most would not fail to stir within him; because we should not dismiss a particular aspect: the invention of the Ictineu was due more to a love for humanity than a love for science. If we did not have to hold this text to a few short paragraphs, we would be able to pause and take up this and other points; here, we shall simply point out that the harvesting of valuable coral and the relatively scarce fruits born to those that dedicate their livelihood to this miserable industry were the motives that incited Narcís Monturiol...”

At the same time, however, Monturiol appreciated the considerable scientific interest that exploring the depths of the sea would generate. This “new continent,” as he called it, would doubtlessly yield great benefits to humankind. But harvesting and exploration were not the only intended ends; like his predecessors, Monturiol saw military applications for underwater navigation, even though in the first few attempts this aspect was relegated to a very secondary role.

Monturiol's underwater navigation project was quite complex. Firstly, he proposed a design in the shape of a fish, which is why it would be named “Ictíneo,” or *Ictineu*, in Ca-

talan, a neologism based on the Greek words for fish and boat.

It was a double vessel, the exterior in the form of a fish, in order to obtain hydrodynamic properties, and the cylindrical interior to provide lodging for the crew. Secondly, he came up with a set of navigational systems, including the means of propulsion, immersion and re-surfacing, isolation of the interior chamber, and air renewal [34]. Thanks to Monturiol's published reports as well as the accounts published by colleagues and collaborators, such as Robert Robert in 1861, there is extensive documentation of their development, which would take place over the next 10 years, from 1857 to December of 1867.

In 1859, two years after setting up a company in Figueres and forming a work team, Monturiol was able to launch the first *Ictineu*, an event that took place in the Barcelona Harbor. The vessel had been built by *mestre d'aixa* (“master boatbuilder”) Josep Missé i Castells, who was a member of the first crew along with Josep Oliu and Monturiol himself (Fig. 3). From then on, the trial *Ictineu* (or *Ictineu I*) would carry out several immersions, some of them for the government authorities, the one in Barcelona in September of 1860 and, later, in May of 1861, in Alicante. The social impact of Monturiol's innovation was significant. The many support groups that sprang up throughout the region would later contribute financially to the project. However, the test in Alicante proved rather disappointing to Monturiol, since the Minister of the Navy was skeptical of using the *Ictineu* as a vessel of war. Monturiol then went to Madrid to try to obtain financial aid from the government. In a letter to Queen Isabel II, he emphasized the “war” version of the *Ictineu*, with the scientific or commercial version left for the public domain.

Monturiol returned to Barcelona rejected and disillusioned, but he was applauded as a hero. Perhaps that is why he found the strength to continue, hoping to acquire private financing to build an operative *Ictineu*. He was received triumphantly in Barcelona, Girona, Figueres, and Cadaqués, where concerts, theatrical representations, assemblies, and other events were held



Fig. 2. Portrait of Narcís Monturiol (1855) by Ramon Martí Alsina (1826–1894). Oil painting over canvas (53 x 43 cm). Empordà Museum, mE970.

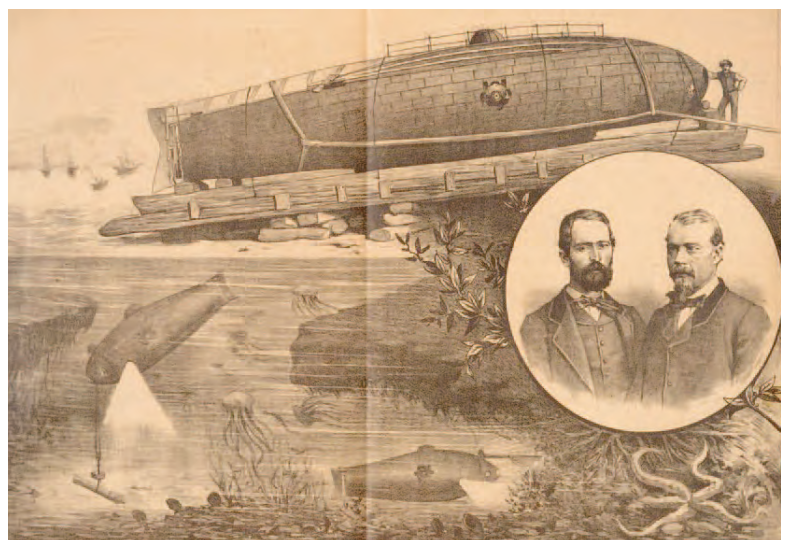


Fig. 3. Launch of the second *Ictineu*, with a superimposed image of Josep Oliu and Josep Missé. The illustration appeared on “La Tomasa” on 5 September 1890.



Fig. 4. Share of “La Navegación Submarina”, property of Antoni Dubé’s, from L’Escala, one of the company’s main shareholders.

in his honor. When Monturiol and his colleagues were certain that they could not count on the government’s support, they started fundraising efforts for the construction of a fully operational *Ictineu*. They were supported by many of the old members of the Barcelona Cabetan cell, such as the musician Josep Anselm Clavé, the novelist Antoni Altadill, and the physician Francesc Sunyer Capdevila. To amass the necessary donations as well as funds from investors, the company La Navegación Submarina (Underwater Navigation) was formed in Barcelona in 1864, with Joan Tutau, of Figueres, as president (Fig. 4).

The company established a new technical office and employed the naval architect Joan Monjo. He had already designed *Ictineu I*, although at the time without being an official member of the technical team [4]. Construction of the second *Ictineu* was again headed up by Josep Missé. Among the new team members were master boatbuilders, artisans, and technicians.

The limitations of the first *Ictineu*, which would render it of little use for subsequent applications, were not just in terms of space but also navigation, especially the fact that it could not travel any faster than one mile per hour. Although academic studies have since affirmed that the *Ictineu* indeed could have grave navigational difficulties, this is not indicated in the majority of testimonies from the era [27,28].

In the second *Ictineu*, certain shortfalls persisted even though Monturiol introduced novel improvements, such as the system for air renewal. He and his team concentrated on propulsion, which was manual, and considered installing a motor.

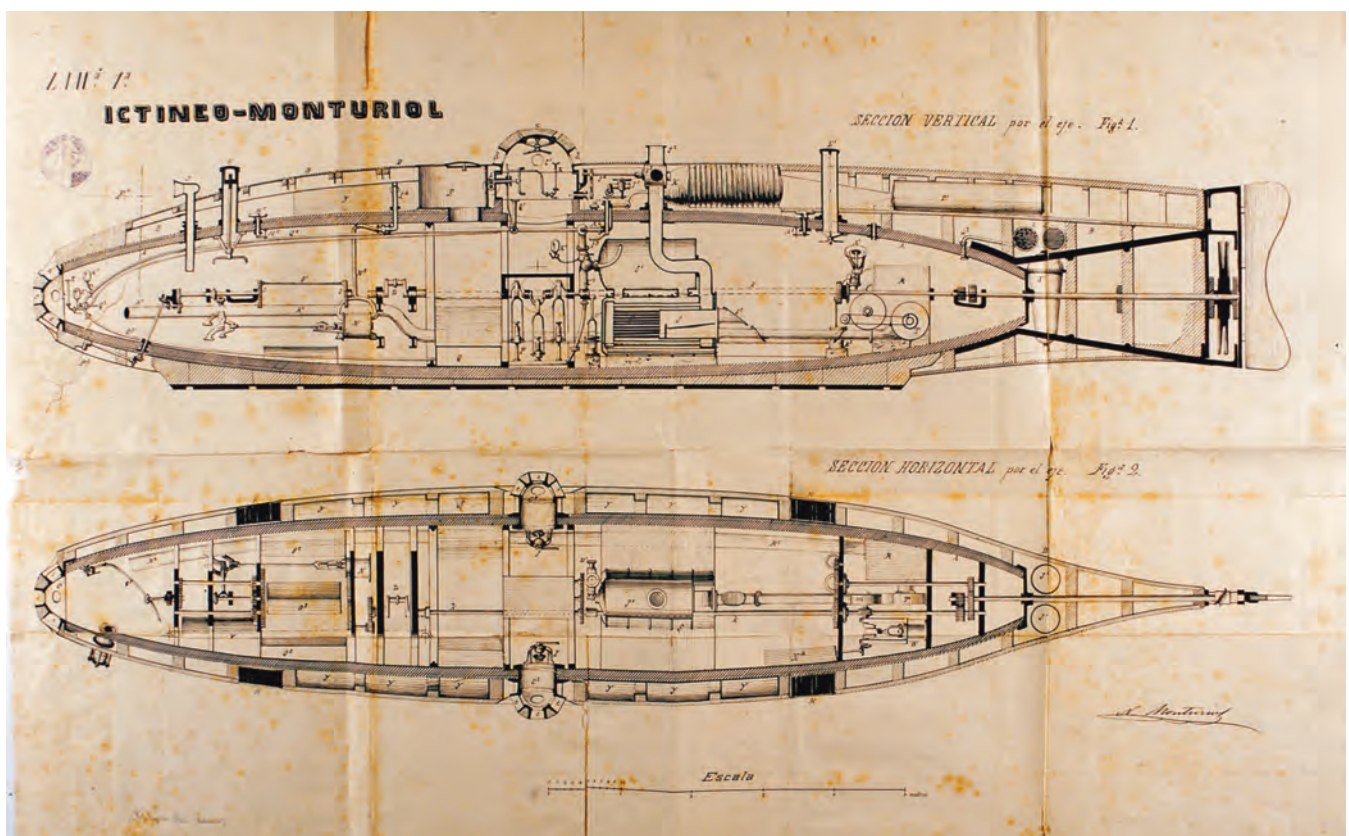


Fig. 5. Plans of the *Ictineu II* which appeared in the *Ensayo sobre el arte de navegar por debajo del agua* by Monturiol (1891).

In light of the technology available at the time, they decided to adopt a steam engine, after having chosen a fuel that produced heat and did not release toxic fumes. The engine was designed to be introduced into the already-built *Ictineu II*, a remarkable assumption considering that the pieces had to be inserted through a foot-and-a-half wide hatch. Nonetheless, installation of the new motor was completed in the summer of 1867, but just as the project entered a full-blown crisis: money had run out, lenders demanded payment, and it was not yet possible to deploy the *Ictineu* for any profitable activities. The few trials with the new steam engine brought no resolution of the crisis such that in December of that year the company had to lay off its entire staff. In the first few months of 1868, the *Ictineu* was put up for auction and subsequently dismantled. Apparently, the steam engine was removed from the vessel and installed in a wheat processing plant in La Sagrera, Barcelona, where it seems to have worked for many years. But, sadly, Monturiol's grand ambitions would remain unfulfilled.

Table 1. Comparison between the two *Ictineus*

	<i>Ictineu I</i>	<i>Ictineu II</i>
Length	7 m	17 m
Width	2.5 m	3 m
Maximum Height	3.5 m	3,5 m
Section of inner chamber	Elliptical	Circular
Length of inner chamber		14 m
Capacity of inner chamber	7 m ³	29 m ³
Speed on surface	0.9 km/h	1-3.5 km/h
Power on surface	4 men	16 men/ 6 HP
Power underwater	4 men	16 men/ 2 HP
Calculated depth	40 m	50 m
Actual depth	20 m	30 m
Crew	5 men	20 men

The years after the dismantling of the *Ictineu*

The engineer Josep Pascual Deop (1844–1919), who later became Monturiol's son-in-law, after marrying his daughter Anna, wrote that the era of the first *Ictineu* was one of public trials, of noisy successes, as well as celebration, unlike the era of the second *Ictineu*, which, according to all indications, was marked by a general indifference to the extent that almost no one cared enough to help avert the vessel's demise and subsequent absolute disappearance.

The project encompassing the physical creation and improvement of the *Ictineu*, forced to an end by its lenders, was a deep disappointment for Monturiol. Despite the burden of this loss, he nevertheless dedicated the following months to writing his major work, *Ensayo sobre el arte de navegar por*

debajo del agua (Essay on the Art of Navigating Under Water) (Fig. 5). In January 1870, he finished the manuscript, which he viewed as his most significant scientific legacy, and wrote the prologue. The *Ensayo* is an all-encompassing scientific treatise on underwater navigation, the first of its kind to lay out in detail the innovations and experiences achieved in the development and testing of a submarine. However, Monturiol did not live to see his great written work in print. His best attempts to have it published, including writing, in 1878, to King Alfonso XII for assistance, were fruitless and the *Ensayo* appeared posthumously, in 1891. Today, it serves as a valuable primary source and contribution to the historiography of the history of science and technology. In the *Ensayo*, Monturiol himself pointed out:

“...I chronicle the studies made, the sources from which I drank, the rules that govern this class of navigation and the principles upon which the submarine chamber is based, named ICTÍNEO by me, from two Greek roots meaning *fish-boat*.” [26]

The *Ensayo* cites texts in Monturiol's collection and those that he consulted, some of which are stored at the *Observatori de l'Ebre* (Ebro Observatory, Roquetes, Tarragona), the place chosen by Joan Monturiol, the inventor's youngest son, who died in 1940.

Political commitment

Monturiol never abandoned his ideological convictions and principles [31]. Even in the midst of soliciting support for the *Ictineus*, he headed a publication, *Almanaque Democrático para el año bisiesto de 1864* (Democratic Almanac for the 1864 Leap Year), in which he and his colleagues (including Clavé, Sunyer i Capdevila, and Tutau) responded to the contents of a very conservative almanac published by the Catalan Ateneu, an entity that Monturiol and his friends belonged to. The Democratic Almanac was cited in the *Index Expurgatorius*—the list of books prohibited by the Catholic Church because they were considered damaging to the faith—due to its secular qualities and for its promotion of “democratic,” i.e., socialist, ideas.

The Revolutionary Sexennium (1868–1874), initiated by the revolutionary uprising of September 1868 (*La Gloriosa*, the Glorious Revolution) and the dethronement of Isabel II, was a period that saw the growth of Republican influence to the extent that, finally, in February 1873, the First Spanish Republic was proclaimed. A quote from Monturiol ran in the headline of *La Vanguardia* (The Vanguard)—the Republican incendiary weekly edited by Josep Anselm Clavé from October 1868 to January 1869—alongside others from Emilio Castelar, Francesc Pi i Maragall and one from Clavé himself. Moreover, Monturiol was one of the deputies in the Constitutional Courts of the First Republic as a candidate representing the city of Manresa in the elections to Congress on 10 May 1873; he was voted in by a wide margin. With the support he received among Republican

sympathizers, he was able to travel to Madrid in the summer of 1873 [38].

The Republic was ephemeral and was finally brought down by the *coup d'état* on 3 January 1874, which restored the Bourbon line. During that period, Monturiol maintained his links to Republican circles, opting among the divisions of the Republican movement for the *Partido Republicano Posibilista* (Republican Party for Promoting Possibilities), whose leader was Emilio Castelar, an ex-President of the Republic. Castelar later served as deputy for Barcelona in the years 1876, 1879, and 1881. In February of the latter year, Monturiol, Emilio Castelar, Josep Tomàs Salvany, and others became honorary members of the Democratic Governmental Committee of Barcelona, presided over by Pau Alsina [36].

Capacity for invention and collaboration with engineers

Even though he had studied law, worked as a typesetter, printer, journalist, and had dabbled in painting, ever since his very first inventions Monturiol preferred to define himself as an inventor. He was convinced of the close relationships that unite facts to principle and which make up the laws of nature. For him, inventing was nothing less than the art of applying observed principles in order to produce prescribed outcomes. These, he said, were inherently artificial because they owed their existence to human industry and did not and never would have the perpetuity, perfection, and self-reproduction that distinguish the natural world.

In 1851, the Escuela Industrial Barcelonesa (The Barcelonan Industrial School)—later, the Escola d'Enginyeria Industrial de Barcelona (The School of Industrial Engineering of Barcelona)—was founded. In spite of Monturiol's technological successes, he lacked formal schooling in engineering. Instead, he was a self-taught man of great intellectual curiosity and well informed of the scientific and technological advances of his era. But what is more, he enjoyed the friendship, counsel, and collaboration of industrial engineers. For the most part, the professors and teachers at the Barcelonan Industrial School came from the technical schools created by the Junta de Comerç de Barcelona (Barcelona Board of Commerce) and were deservedly renowned, both within the city and outside it [34]. Several of the professors had received their degrees in France and still maintained contact with the industry and educational centers there.

By virtue of the underwater navigation project and the construction of the *Ictineu*, Monturiol had established professional relationships with Barcelona's scientific elite. Among those who supported his first project, described in an 1858 publication by Monturiol [24], were scientists linked to the Industrial School [25]:

"The director and professors from the Barcelonan Industrial School, Don José Roura, Don Pedro Roqué y Pagani, and my friends Don Lorenzo Presas, Don José Giró y Roma and Don Juan Monjo, and other professors of the natural sciences and mathematics, all gave me the encour-

agement to pursue this undertaking until I achieved definitive results."

Josep Roura [6] and Pere Roqué were chemistry professors; Llorenç Presas, a scientist of a very unique abilities, was professor of mathematics at the Industrial School [29]; Josep Giró was a professor at the Escola Normal de Barcelona (Normal School of Barcelona) and a member of the Academy of Sciences [7]; Joan Monjo, the last to be mentioned, was a naval architect who, as noted above, eventually became a very active participant in the *Ictineu* project and in the construction of the second prototype [40].

The Industrial School was considered the most significant scientific-technological institution in Barcelona. Its director, Josep Roura, who was one of the highest authorities on chemistry in Catalonia, vociferously gave his support to the *Ictineu* in an 1860 text:

"I believe that the means you use for the movements of descent and ascent, to steer right and left, forward and back, are appropriate for this object; I believe that those it uses to feed artificial light under the water will have the results you are hoping for and, finally, I believe that the substances you use for getting rid of carbonic acid, water vapor and the heat we produce in breathing and sweating are appropriate to the ends you suggest, and that, with the addition of oxygen in proportion with what we spend of it, will give you purer air within the boat than the air that we breathe in this room." [25]

In that same year, while attempting to gain scientific backing for his project, Monturiol addressed the Catalan Ateneu, which subsequently published a report about his invention [33]. The Ateneu had formed a special commission—presided over by Josep de Letamendi, Professor of Anatomy from the Faculty of Medicine—made up of several of the city's renowned professors, representing the Academy of Natural Sciences and Arts, the Naval School, and other institutions. At the time, the president of the Ateneu was Joan Agell i Torrents, director of the Industrial School after the death of Roura in May of 1860. The commission's report was very favorable toward Monturiol's invention and very explicitly noted that the body's president had actively participated in its work. Agell advocated continued support of the *Ictineu* project, in step with the position of his predecessor, Josep Roura.

Thus the Industrial School was one of the first backers of Monturiol's efforts. Among the many professional engineers who eventually joined the project was, Josep Pascual Deop, a young industrial engineer in charge of the design and installation of the steam engine in the *Ictineu II*. As mentioned above, he later married Monturiol's daughter.

Another active collaborator in the project was the Industrial School professor Damas Calvet, also from Figueres [32]. Calvet was an industrial engineer who specialized in chemistry in addition to teaching industrial drawing and serving as professor of "Projects" at the school. Together with Monturiol, he carried out experiments on obtaining oxygen and eliminating car-

bon dioxide; the two men worked in a laboratory in the Barcelona neighborhood of Poble Nou [21]. Calvet became a close friend of Monturiol and documented many of his inventions.

Monturiol the inventor

In a letter dated 21 March 1874, written to his wife Emilia while in Madrid, Monturiol defined himself as an inventor, after mentioning that he had done all kinds of work: “journalist, typesetter, printer, notebook maker, portraitist, a man of science, inventor...and will possibly die poor” [8]. From this point on, we will review Monturiol's main inventions, setting aside his underwater navigation project.

A machine for printing the notebooks of lined paper used by school children and students was Monturiol's first known mechanical invention. Previously, the pages were manually cut, but Monturiol designed engraved cylinders equipped with a special system to supply them with ink. Thus, a sheet of paper on a paper roll would be stamped and then mechanically cut by a small saw as it left the cylinder. The simple movement of a crank allowed the cutting and folding of the notebooks from the roll of paper. Monturiol teamed up with Josep Oliu, then a revolutionary colleague, to capitalize on the invention [19]. Technically, the machine worked, but not the business side of the venture. Later, the machine was bought by a textbook publisher. In more economically adept hands, it could have made a fortune, but, despite his many skills, Monturiol lacked the business acumen to profit from either it or most of his other inventions, as discussed below [19].

Besides underwater navigation and the *Ictineu*, surely Monturiol's most outstanding invention was a machine for manufacturing cigarettes. According to Calvet, Monturiol invented it with the help of a friend while working on the *Ictineu* [9]. In 1866, confronted with financial problems from the expenses generated in installing the steam engine for the *Ictineu II*, Monturiol patented the machine [29], with the goal of securing a source of additional income. According to the patent document [37], the machine's shape was similar to that of a power loom; the cut tobacco was introduced into a funnel; the machine made 22 movements and produced 45 cigarettes per minute. It included an attachment that pushed the finished cigarettes into a box. Monturiol offered the machine to the Sucini brand in Havana but it seems that, in the end, the company refused to pay the asking price of 30,000 duros (1 duro = 5 pesetas) for the machine and the patent [20]. Monturiol then intended to distribute the cigarette-producing machine and to profit from it himself. On 3 March 1867, he formed a company with Frederic Borràs, Josep Oliu, and others for its production and distribution, ceding rights to the invention to the Borràs i Cia. company, in which he was a shareholder [34]. In 1870, in accordance with the shareholders interests, he tried introducing the machines to state-run factories. The machines were exhibited by Borràs at the General Catalan Exhibition celebrated in Barcelona in 1871, where it received a medal [39].

At the start of 1871, the Tobacco Administration allowed

one of the machines to be used in the manufacture of cigarettes. Nevertheless, it was not well received by Madrid cigarette makers and in a factory riot on 7 June 1872 it was destroyed. A long line of legal processes was necessary to receive the 19,940-peseta compensation, which finally occurred on 21 September 1874. Around the same time, Borràs sought to disassociate himself from Monturiol and managed to appropriate the invention. Although at first it was commercially successful, Borràs ended up insolvent and went bankrupt. Nonetheless, at the time of Monturiol's death, many of these machines had been built and were being used in tobacco factories in Cuba, Mexico, and Portugal. Monturiol perfected the prototype, managing to create a smaller, tabletop version that could be hand operated by one person and which quickly rolled the cigarettes one-by-one. This was the only invention that produced an inheritance for Monturiol's family [19].

When Monturiol was in Madrid in 1873, he was named director of the National Stamp Factory. The Minister of the Treasury ordered the creation of an enormous quantity of stamps intended to raise funds for a new war tax. They had to be made in such short order that there was hardly time to apply the glue to the stamps. Monturiol considered installing vapor dryers, but no manufacturer would commit to having the needed coils and tubes ready on time. With the collaboration of the factory's metalworkers, he built a drying system for glue-bonded stamp paper and, before the Ministry's due date, one million stamps were being made daily.

As mentioned earlier, in the year 1873, during the First Republic, Monturiol was a deputy in Congress. The Republic had formed shortly after the outbreak of the Third Carlist War. The conflict seems to have been the motivation behind Monturiol's invention of a new device, which he referred to as a “successive discharge cannon.” This was a field cannon intended for use by the infantry and based on the incomplete combustion of the powder used in normal cannons. He believed that by dividing the charges into separate layers, a bigger effect could be produced, since the combustion would come off completely and the projectile would receive the full force of the charge [19]. The cannon weighed 176 pounds (including the case), which made it easily transportable by mule through mountainous and treacherous terrain. It had a range of up to 2187 yards and the price of each cannon was about 1000 pesetas [34].

At the beginning of 1874, Monturiol began to redesign the small cannon known as a culverin. His bronze “portable-cannon-culverin” was “a little less than 2 mm in wall thickness and 4.25 feet in length; it was mounted on wood like a weapon used off the shoulder” [34]. However, until 13 April 1874, a lack of resources prevented him from testing it. He finally did so in Madrid's Casa de Campo Park, but the weapon was destroyed in the process. Monturiol understood the reasons for the failure but was unable to obtain further resources that would allow him to make the needed improvements.

Upon his death, Monturiol left behind numerous devices, protocols, and studies that were completely finished, others that were nearly so, and even more that were still in the planning phase. Among those completely finished projects are those based on his chemical investigations. One such project

was intended for the improvement of wine. Thus, Monturiol would counsel his friend Francesc Rahola ("Lito") on July 30, 1880:

"...before the harvest, choose a bunch of ripe grapes (red ones, so that the wine will have color) and after a good pressing, put it in an appropriately sized bucket and then pour in a wineskin of water with 16 pounds of sugar. Strain it as usual and, depending upon the kind you have achieved, you will be able to decide whether to repeat the experiment on a large scale or to abandon the system. If the wine turns out too strong, decrease the amount of sugar; if it turns out sweet, you should also decrease the sugar." [11]

In the letters that followed, Monturiol showed himself to be an expert in wine production, not only counseling Rahola but also convincing the School of Industrial Engineers to analyze the wine samples that Rahola had sent him after following his advice [12].

Monturiol's other completed projects included a printing ink, a velograph (a mechanical device for copying letters while they were being written), and liquid glue for use by woodworkers and cabinetmakers. Other inventions were a cold-produced soap—an early idea that he took up again in 1874—and a means of conserving substances, especially fresh meat. It was mostly in 1882 that Monturiol dedicated his efforts to the conservation of foodstuffs. He hoped to be able to use the meat-preserving method in a business that he organized with his friend Martí Carlé, who lived in Buenos Aires.

"We pampered ourselves today, trying out a piece of meat that had been preserved for eight days and had still not lost any of its qualities of fresh meat. If I pull this off within a time-frame of one or two months, it will be a lucrative business." [13]

He continued testing the procedure in 1883 but despite its success it would remain unexploited. One of his assistants, Josep Llovera, took advantage of Monturiol's lack of business sense and, passing himself off as an engineer and industrial chemist, sold the technology to the Barcelona livestock merchant Joan Serra i Bertran. Llovera disappeared but eventually turned up in London where he created a financial entity and amassed a large fortune [34].

Amongst the nearly finished inventions were an apparatus for testing clocks based on the invariability of their axes of rotation, and a conical telescope. Monturiol also left notes on the construction of a mechanical bird, evidence of his interest in flight and aerial navigation. Another uncompleted invention was a domestic motor of "8 kilogram-force to 1 horsepower," according to Damas Calvet [19]. This invention seems to have been a response to an American news story about a sewing machine. For its creation, he asked for financial help from Josep Tomás i Salvany (1839–1905), a Republican colleague who was also an active member of the Democratic Party and later of the Republican Party for the Promotion of Possibility [15]. In 1873, he was one of the Catalan deputies in the Constitutional Courts, as was Montu-

riol. Tomás was also active in industry and business and owned a farm. In March 1879, he loaned his colleague 2000 reales for his studies on "a new receiver for vapor power." Monturiol wrote in May of that year [16]:

"It is of little import whether the sewing machine moves by way of foot or hand, as it has up until now, or whether with the weight and balance of the body, as referred to in the American article. What is of interest is a simple, cheap, inanimate motor occupying little space that is not given to the normal eventualities of the steam machine and of the steam boiler, and that is applicable to all types of work, especially small-scale industries...The domestic motor will restore the balance of power between family and society, between towns and populous centers... Should you help me, don't doubt that I will manage to make the home motor practical, assuming that the first trials correspond with my projections."

Typically, however, in July of 1879, Monturiol began to encounter serious difficulties in moving ahead financially with the project. At the time of his death, several projects were still in the planning phase, including a procedure for making an artificial shoe sole, another for transforming wood into glucose, and another for reinforcing iron with a coating of its own sulfur.

In addition to all of the above projects, further experiments can be added to the list: the manufacture of starch from potatoes [38], the construction of wheat mills, and methods for bleaching wheat. He also sought to improve the breeding of farm animals and, while in Madrid, performed experiments on converting wood from the willow tree into a food substance for rabbits. His ideas knew no bounds; he prepared a shoe shine "that shines with just the touch of a brush" and undertook a project on a gyratory vapor receiver. He completed the latter toward the end of 1878 and then sent it to be installed in the "La Española" thread and fabric factory, which his son-in-law ran in Sant Martí de Provençals [20]. From the beginning of 1880 to July 1882, Monturiol devoted his Sunday afternoons to his inventions and to discussing his ideas with friends and colleagues [17].

Monturiol also became interested in a funicular tram project for Tarragona that the bank he worked for at the time was looking to construct. He also followed up on a suggestion of Martí Carlé, his friend from Argentina, regarding a project to mechanically cut stones at right angles in order to produce flat cobblestones for paving streets.

Tragically, Monturiol's seemingly endless capacity for invention was seldom accompanied by a similar capacity for securing and managing financial resources, an absolutely essential element in carrying out the trials and experiments needed to realize, commercially exploit, and ultimately profit from his devices. Monturiol himself was aware of this limitation:

"As a printer, I don't stop until I print the roll of paper; as a smoker, until I make mechanical cigarettes; and as a man, until I create the *ictinea* chamber, capable of sustaining life in unsuitable environments, be it in the sea or out of it; as a

physicist, I have the underwater motor and the aerial one, etcetera, etc., because I feel I have the intellectual might for anything... yet, I don't know how to do business, nor do I know how to win men over so that they will come to my aid." [34]

The final years

With his family, the inventor was very affectionate, as evidenced in his letters, where he wrote, "For me, my wife and my children were, are and shall be the sky of my existence" [38]. Monturiol had eight children, of which only three survived: Anna, Emili, and Joan. Infant mortality was very high in that era and three of his children died very young. However, Monturiol's heaviest personal blow came just a few years after the failure of the *Ictineu* projects, in the form of the premature death of his two teenage daughters, one from tuberculosis at 17 years of age and the other, shortly thereafter, at age 13.

During those difficult years, Monturiol continued to pursue his interests. Stored at the Maritime Museum of Barcelona are manuscripts of texts of lectures that he gave in Republican circles. He followed up on his interest in cosmology, astronomy, and geology, writing *A General Idea of the Universe* (December 1874), *On Comets* (January 1875), *Igneous Meteors* (January 1875), and *Geosophy. Geological Part* (April 1875), following the works of authors including Humboldt and Arago. Monturiol also co-authored and co-edited *Celebrated Men and Women of all Eras* (1875–1877), published in two tomes comprising biographies of historic personalities, such as Gutenberg, Galileo, Newton and Watt.

He also left a completely finished report entitled *Investigations on the Cause of Gravity* that, according to Calvet, proposed a general theory of the universe [19]. His study on the theory of gravity was started toward the end of 1878 and he continued to work on it during the last years of his life [34].

In 1878, in order to earn a living, he accepted an administrative position at a new newspaper called *La Corona* (The Crown) and, at the end of 1879, worked at the office of a stockbroker and, later, as the company's cashier. In 1880, he wrote to his friend Francesc Rahola of Cadaqués:

"...finally, in order to live, I had to accept being the cashier of a broker who's a relative of mine. I spend all day counting money and all kinds of publicly and privately held commodities and I only earn 30 duros."

A year later, he joined the administrative board of an organization set up by the company to bring the waters of the Ter river to Barcelona. In the summer of 1882, he changed jobs and oversaw the editing of the *Anunciador Financiero* ('Enunciator Financier'), a brochure that was sent out every fifteen days to the clients of the Banc de Mataró, but in September of 1883, the bank was liquidated.

After falling ill, Monturiol was moved to the home of his daughter in Sant Martí de Provençals, where he passed away on September 6th, 1885. It was said that he died, forgotten by every-

one. The facts, however, show that at the time of his death he still had quite a reputation. In fact, on the day of his burial, his fellow Republicans announced an event to pay him homage. Although it was prohibited by the governor it could not be prevented, and took place one week later.

In 1889, Isaac Peral i Caballero (1861–1895), an official of the Spanish Navy, constructed a torpedo submarine—based on a design much ahead of its time—that was propelled by an electric motor. Peral had recognized Monturiol's genius and the enormous progress he had made in solving the problems of underwater navigation. With the success of Peral's invention, the Catalan press published a series of articles in praise of Monturiol. His son-in-law, Josep Pascual i Deop, was very much engaged in this acclamation, detailing, in an article that ran in an 1890 supplement of the newspaper *La Vanguardia* dedicated to the *Ictineu*, the different trials that were performed with the *Ictineu* [18]. The following year would finally see the publication of Monturiol's *Ensayo*, thanks to the financial support of employers of the *Compañía Transatlántica*, where Joan Monturiol, son of the inventor, was working.

Conclusion

It is widely assumed that the end of the project of the two *Ictineus* represents the end of Monturiol's work. As shown here, however, this assertion is not true, neither from the perspective of his political and social commitments nor based on his intellectual pursuits and seemingly infinite capacity for invention.

The near-mythic status of Monturiol lies in his lone attempts at underwater navigation, in the lack of comprehension that stymied the realization of his ideas, and in the attempts by his associates and by those who followed at usurping his merit and his due benefits as an innovator. Throughout his professional life, Monturiol was closely linked to the world of professional engineering, then an emerging field in Catalonia. In this regard, he represents the transition between practical engineering and professional or technical scientific academic engineering [23].

Finally, Monturiol was a man of commitment throughout the course of his life. He maintained his socialist and republican convictions, even when they stood in the way of realizing his technological endeavors.

Notes and references

Notes

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- [8] This intimate friend who is the author of this assertion was most likely Damas Calvet, although he did not sign the article. See the magazine *Industria é Inventiones* no. 90, IV:117-118
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